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Skeletons Testify: Anthropology in Forensic Science AAPA Luncheon Address: April 12, 1996

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Forensic anthropology, especially as practiced in North America, involves the application of our knowledge of physical anthropology to the identification of skeletonized human remains and related legal problems. As such, the field represents the "applied" side of human skeletal biology. Physical anthropologists trained in skeletal biology frequently possess the knowledge and experience in the archeological recovery of human remains and their research interpretation that are uniquely needed by authorities and colleagues in forensic science in the investigation of human remains recovered in a forensic context. Increasingly, anthropologists are called upon to interpret such remains and to present their findings to the relevant authorities. Growth of forensic anthropology has reached the point that it now can be thought of as a subdiscipline of physical anthropology. However, the relationship between forensic anthropology, skeletal biology, and related areas of physical anthropology remains strong and symbiotic. This essay explores this relatively new endeavor and its evolving relationship with the more general field of human skeletal biology.

CONTRIBUTIONS OF FORENSIC ANTHROPOLOGY

What attracts growing numbers of respectable anthropologists to forensic science? The answers to that question are complex but basically are four. 1) Forensic work frequently involves offering opinions that can lead to identification. Once the remains are identified, the known facts about the individual and what happened to him/her offer an opportunity to assess the accuracy of our existing techniques and expand the scientific data base. 2) The cases offer unique information about taphonomic change, skeletal effects of trauma, correlations between skeletal indicators and medical records, and other aspects. This information is needed to properly interpret archeologically recovered human remains that skeletal biologists otherwise examine. 3) Forensic analysis yields unique information about the skeletal biology of contemporary populations. 4) The field offers us an important opportunity to apply our knowledge and skills toward the resolution of problems of contemporary society.

In the author's experience, the relationship between the forensic work and research with archeologically recovered human remains is very positive. The archeological experience provides the knowledge and techniques that make us unique contributors in the forensic sciences. Conversely, the experience and knowledge gained in forensic work allow interpretations with archeologically recovered remains regarding taphonomy, trauma and related areas that would not otherwise be possible.

HISTORY

The roots of modern forensic anthropology extend back to the very foundation of American physical anthropology. Although Aleš Hrdlička (1869–1943) published relatively little impacting directly on the forensic applications of physical anthropology (Thompson, 1982), according to T.D. Stewart (1979) he occasionally had contact with law enforcement officials in the identification of human remains. Documents located in the Hrdlička Collection within the National Anthropological Archives at the Smithsonian Institution's National Museum of Natural History reveal that, as early as 1931, he reported on a forensic case from Arizona (Halseth corre-

spondence, 1931–32, Hrdlička Papers/National Anthropological Archives). Reports and correspondence from Hrdlička indicate that he consulted for the FBI and communicated with its director, J. Edgar Hoover, in 1938 and 1940 (Department of Justice correspondence, Hrdlička Papers/National Anthropological Archives). Hrdlička's greatest contribution to forensic anthropology involved laying the foundations of science and collections that would allow the field to later develop and flourish.

Many credit Wilton Krogman's 1939 short publication in the *FBI Law Enforcement Bulletin* as formally launching modern forensic anthropology (Stewart, 1979; Thompson, 1982). Although the publication itself offered only general coverage of the science, the *Bulletin* brought visibility of the field to a major segment of the law enforcement community. Krogman also began the tradition that is now so important to the field, of scientists directing their writing and research skills directly toward the forensic arena. Krogman's efforts in this regard culminated in his own 1962 classic text, *The Human Skeleton in Forensic Medicine.*

Research directed toward forensic anthropology strengthened considerably through the efforts of Hrdlička's Smithsonian successor, T.D. Stewart. Beginning in 1942, Stewart continued a long Smithsonian tradition of regular consultation in forensic anthropology with the FBI Laboratory. Unlike Hrdlička, Stewart joined Krogman in devoting considerable research and writing attention to forensic applications, including his own text (1979), a volume on identification in mass disasters (1970), and his classic 1957 monograph with Thomas McKern on age changes documented in the Korean War dead. Beginning with World War II, the need to identify remains recovered from United States military engagements has increasingly required the services of forensic anthropologists, leading to the establishment of today's modern identification facility at the United States Army Central Identification Laboratory at Hickman Air Force Base, Hawaii.

In 1962, J. Lawrence Angel joined the Smithsonian staff when T.D. Stewart was appointed museum director (Ubelaker, 1990a). Although new to the forensic applications of skeletal biology, Angel assumed consultation with the FBI and rapidly shifted his academic interests toward forensic anthropology. Angel remained the primary consultant for the FBI until 1978, when the author assumed that responsibility. From 1962 until 1986, Angel reported on 565 cases and launched a training program in forensic anthropology at the Smithsonian that continues today. During Angel's period of forensic activity (1962 to 1986), forensic anthropology rapidly grew as a science and in public awareness, partly due to Angel's own efforts of teaching and professional activity.

In 1972, physical anthropologists formed their own section of the American Academy of Forensic Sciences. This important historical development offered those interested in this area an annual meeting to present research results and discuss cases. The *Journal of Forensic Sciences* emerged as an attractive alternative to the *American Journal of Physical Anthropology* as a publication outlet. Membership in the physical anthropology section of the American Academy of Forensic Sciences grew rapidly from an initial membership of only 14 in 1972 to 202 in 1996, reflecting growing academic interest in forensic anthropology (Fig. 1).

In 1977, section members devised a certification procedure. The resulting diplomate program certifies forensic anthropologists who hold the Ph.D. degree in physical anthropology with a specialization in skeletal biology, have experience in forensic applications, are permanent residents of the United States or Canada, and successfully pass an examination given at the annual meeting of the American Academy of Forensic Sciences. Certification provides the legal system and those seeking the services of forensic anthropologists assurance that individuals included have the minimum necessary skills. The number of board-certified diplomates has grown from the initial 22 in 1978 to 46 in 1996. Numbers of individuals registered as members in the physical anthropology section have increased more than the number of diplomates. In 1978, 61% of members also were diplomates. Subsequently, this

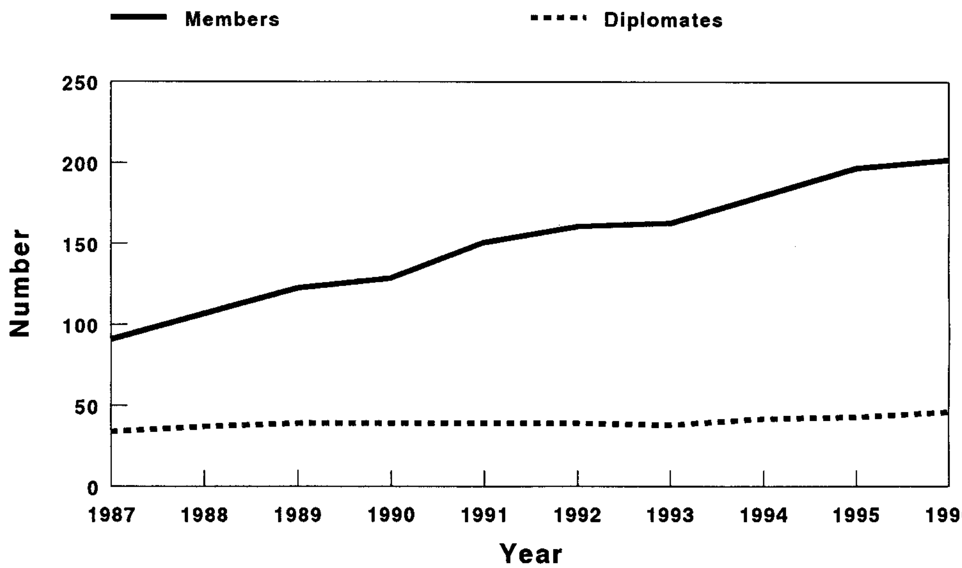

Fig. 1. Comparison of the numbers of diplomates, ABFA, with the numbers of members of the physical anthropology section, AAFS, from 1987 to 1996.

percentage has decreased to only 23% in 1996.

Increasingly, forensic anthropologists have chosen to publish in the *Journal of Forensic Sciences* rather than the *American Journal of Physical Anthropology.* Figure 2 compares the percentage of articles in the *American Journal of Physical Anthropology* on topics relating to forensic anthropology in successive 5-year periods with those published in the *Journal of Forensic Sciences.* Since the high figure of 7.2% from 1956 to 1960, the figures for the *AJPA* have remained stable through time. In contrast, the number of articles of similar foci published in the *Journal of Forensic Sciences* has increased dramatically since the formation of the physical anthropology section of the American Academy of Forensic Sciences in 1972. The percentage of articles in the *Journal of Forensic Sciences* on forensic anthropology topics has increased steadily from less than 1% in the 1960s to over 10% in the 1990s. This increase reflects 1) the policy of the American Academy of Forensic Sciences that the *Journal of Forensic Sciences* has first publication rights to papers presented at its annual meeting; 2) the format of the journal with its "case studies" section; and 3) the desire of forensic anthropologists to communicate the results of their research to others in forensic science.

Each year, to maintain their status, diplomates in forensic anthropology are required to summarize the number and types of cases they have reported on. This information offers an opportunity to track the work being done in this field, at least by the diplomate group. Analysis of these data by Reichs (1995) reveals that the total number of cases reported has increased from 571 in 1984 to about 1,630 in 1992. Most of these cases originated with requests for assistance from medical examiners or coroners, but also include law enforcement officials and the military. The number of civil cases involving anthropological consultation also has increased dramatically since 1988. Anthropologists predominately study skeletonized cases, but also examine fresh, burned, decomposed, and mummified remains. Reichs' 1995 analysis reveals temporal variability in the use of such specialized techniques as facial reproduction, photographic superimposition, photographic comparison, and microscopic age estimation. Anthropological

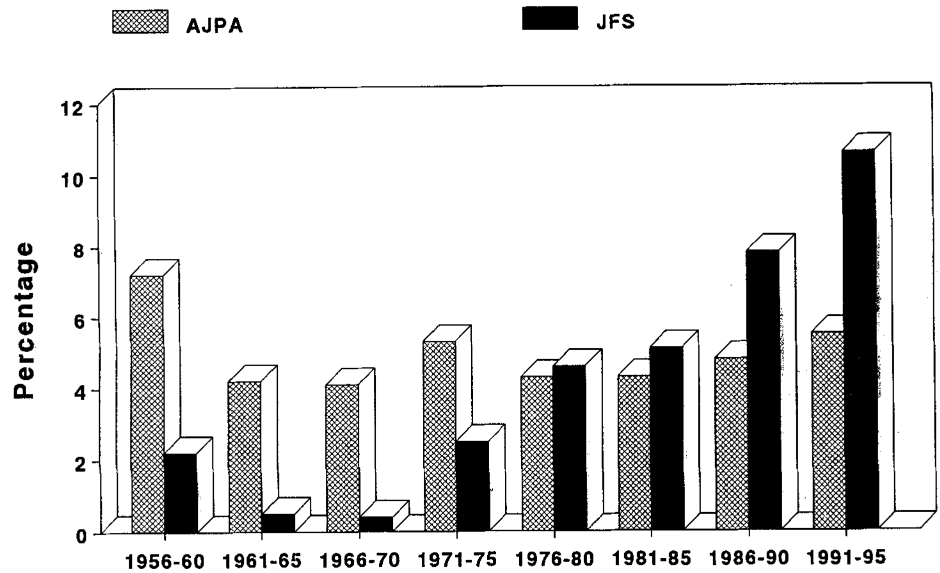

Fig. 2. Comparison of the percentage of all articles published in the *American Journal of Physical Anthropology* and the *Journal of Forensic Sciences* that relate to forensic anthropology.

involvement in evidence recovery at the site, as well as assistance in examination of mass disaster victims, has increased. According to Reichs (1995), in 1992, 13 diplomates were deposed 64 times and 12 diplomates testified in court 46 times. The 1992 diplomate activity was primarily initiated by the prosecution of criminal proceedings; however, civil cases and defense work are also well represented (Reichs, 1995).

TRAINING IN FORENSIC ANTHROPOLOGY

Training in forensic anthropology as practiced in North America has evolved within the framework of teaching human skeletal biology. Most forensic anthropologists have been physical anthropologists with graduate training in a department of anthropology offering special academic emphasis on skeletal biology and its forensic applications. Training at these institutions has varied over the years as personnel have changed and many more institutions have become involved in recent years with the numerical increase in university-based forensic anthropologists. Although education programs in forensic anthropology increasingly have incorporated training in law, radiology, and related areas of forensic science, as well as internships with actively practicing forensic anthropologists, most training has remained centered within physical anthropology. This broad-based education in physical anthropology is ideal and should be continued, since the comparative, population approach, collections-based research orientation and other skills acquired in such programs are the very attributes that make forensic anthropologists such unique and valuable contributors to forensic science.

Considerable training in forensic anthropology also has been available through a variety of seminars and short courses. An early version of such a course was offered for many years on an annual basis by the late J. Lawrence Angel at the Smithsonian. This course continues to be offered by the author and colleagues and recently has been held every other year in France (1992, 1994, 1996). Similar courses are offered by the Armed Forces Institute of Pathology and others and are attended by forensic pathologists, dentists, anthropologists, and a variety of other professionals who seek training in this area. Such courses function primarily to educate

nonanthropologists about the contributions that anthropologists potentially can make to forensic investigation, but also to provide anthropologists in attendance with exposure to approaches that may supplement their previous training and experience.

SCIENCE IN A LEGAL CONTEXT

Increasingly, forensic anthropologists present testimony in court. Their individual qualifications, as well as the relevance of the science itself, must be evaluated and accepted. Is the expert a reliable objective scientist speaking to the evidence or a "hired gun" who will use his/her credentials to support opinions of those who retain him/her? As in the past, the majority of jurisdictions in the United States rely upon the "Frye standard" (*Frye vs. United States,* 293 F. 2d 1013 District Circuit Court, 1923) to evaluate the testimony. This standard basically examines the "general acceptance" in the scientific community of the field of science and the procedures employed. Although such general acceptance is very difficult to define, it basically involves an analysis of 1) whether the general field encompassing the underlying theory is generally accepted by the appropriate scientific community and 2) whether the available procedures produce reliable results and whether those procedures are generally accepted by the scientific community.

In 1993, *Daubert vs. Merrell Dow Pharmaceuticals,* 113 Supreme Court 2786 (1993) generated Federal Rules of Evidence rulings that superseded Frye "general acceptance" tests of the admissibility of certain scientific evidence. With the Daubert ruling, the trial judge still must evaluate the scientific evidence to ensure relevance and reliability. The focus of the evaluation has to be on the procedures and principles and not generated conclusions. Daubert asks the court to consider in its assessment such factors as testing and evaluation, peer review, rate of error, and "general acceptance." Clearly, most procedures employed in forensic anthropology evaluation result from peer reviewed research and are generally accepted within the field. At times, the problems presented for forensic interpretation are such that the investigator must use general knowledge and experience to offer evaluation and opinions. It has yet to be determined how court interpretation of the Daubert ruling might regard the variety of evaluations that forensic anthropologists and other forensic scientists are asked to make. Such evaluations can involve considerable interpretations based on experience that are not easily quantifiable. At times, such opinions are expressed in differing levels of "probability" rather than the "scientific certainty" and more quantifiable results that can easily be evaluated. Clearly, if the experts on both sides of the adversarial process agree, then the procedures are much less likely to be questioned. However, increasingly, both sides offer expert opinions in forensic anthropology and in those situations disagreements can occur.

RECOVERY OF HUMAN REMAINS

Frequently, recovery of remains represents the first step in forensic anthropology involvement and one that utilizes our archeological training. The process of locating likely sites of buried human remains may include techniques largely developed in assessing archeological sites, e.g., aerial photography, assessment of ground vegetation patterns, surface topography, use of a proton magnetometer, ground penetrating radar, probes, surface collecting, and survey. Cadaver dogs (canines trained to smell decomposed human remains) have proven useful in the detection of remains. Excavation largely follows standard archeological practice with full photographic documentation.

Although these techniques are becoming recognized in the forensic community and increasingly employed, anthropological involvement in specimen recovery should be increased. Most standard crime scene personnel have limited experience with these techniques and do not have the osteological skills to recognize fragmentary or altered human remains. Often, personnel will proceed with recovery efforts until problems develop and then request anthropological assistance. The investigation of the aftermath of the Branch Davidian incident in Waco, Texas presents a case in point. Following the fire, authorities recovered remains of iso-

lated individuals from within the Branch Davidian compound area. When they discovered that a remaining structure, "the bunker," contained additional decedents buried within a matrix of rubble and large quantities of weapons and ammunition, they requested anthropological assistance. Using archeological techniques, anthropologists and other professionals isolated and recovered 33 individuals from that structure and then worked with the medical examiner's staff to assist in the identification of the charred and incomplete remains (Ubelaker et al., 1995).

ANIMAL VS. HUMAN

Some of the greatest challenges and learning experiences in forensic anthropology derive from the seemingly simple task of determining if evidence is human or nonhuman. With fragmentary and especially burned remains, human bone can be difficult to recognize. In the aftermath of a structure fire, burned drywall, plastic, wood, and other materials can resemble bone. Since an intense fire can cause extensive bone fragmentation, distinguishing the human fire victim from the residue of the structure can present a challenge to even the most experienced forensic anthropologists. In such situations, effective use of the microscope can be helpful. Microscopic analysis offers an opportunity to examine subtle morphological expressions that allow accurate determination (Ubelaker, in press).

Even complete specimens and large fragments can challenge interpretation. One case from Alaska involved a segment of bone 164 mm long that had been found isolated in a remote area. Carnivores had obviously chewed the ends of the bone and likely had separated it from the rest of the skeleton. The long bone diaphysis displayed an ununited but extensively remodelled fracture that had been bridged with a surgically implanted metal brace (Ubelaker, 1989). The bony response around the margins of the brace indicated the surgery had taken place long before death. When the specimen was submitted to the FBI for analysis, previous efforts to trace the metal plate in an attempt to identify the surgeon and the hospital where the surgery had taken place had failed. Initially, the evidence for surgery had been interpreted as an indicator of human origin for the specimen. Later, radiographic studies suggested the presence of a nonhuman pattern of cortex morphology. Microscopic analysis of cortical histomorphology revealed a nonhuman pattern. The orthopedic surgeon had not been located because the surgery had been conducted by a veterinarian. We later learned that many veterinarians use the same type of orthopedic devices as do the orthopedic surgeons who treat human patients. Such devices now are marked in a way that they can be traced to the patient (Ubelaker and Jacobs, 1995), but if surgery was conducted long ago, identification may still be a problem.

In a Virginia case, a mandible fragment was found at a construction site by an artifact collector. Although the species represented by the mandible was not recognized by the finder or the police authority he contacted, one of them observed an apparent dental filling in one tooth (Fig. 3). Comparison with collections at the Smithsonian revealed that the tooth belonged to a pig. FBI analysis of the metal in the tooth revealed an aluminum content. Apparently this foraging pig had chewed on some aluminum foil, unintentionally packing the metal into a crenulation between tooth cusps.

Pathological conditions offer both exceptional challenges and learning opportunities for the forensic anthropologist. In 1988, two calvaria were submitted for analysis from Oklahoma. Carnivores had apparently removed most of the bones of the faces, but the calvaria were largely complete, revealing humanlike rounded vaults, large open bregmatic fontanelles, and unusual supraorbital grooves. The open bregmatic fontanelles and immature-appearing bone clearly indicated infant status. Because of the dome-shaped vaults, authorities had investigated the possibility of their being human, but no identification had been made. Comparison with collections in vertebrate zoology found a close match of the grooves, as well as the form of the occipital condyles with those in crania of cattle; however, the normal elongated morphology of the bovine cranium did not match with the rounded vault of the forensic

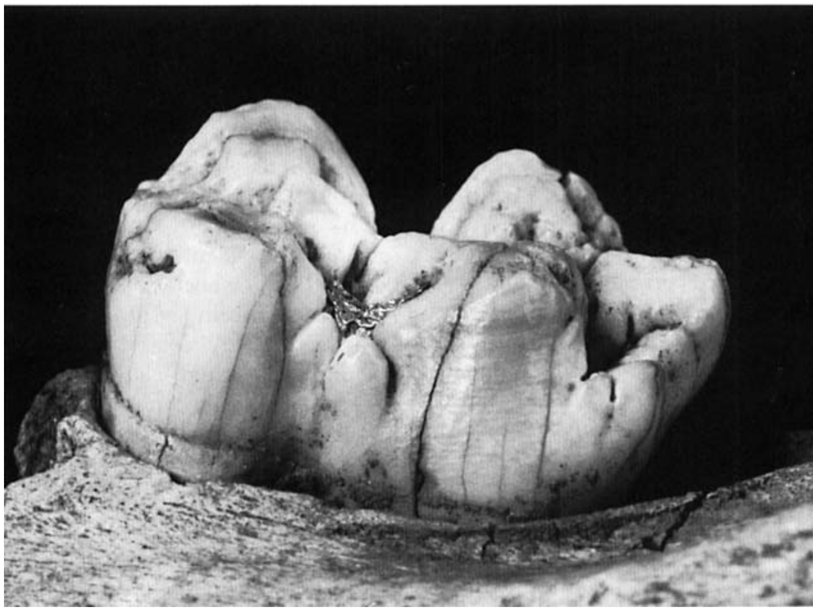

Fig. 3. Mandibular molar of a pig, showing impacted metal.

specimen. Analysis of associated hair revealed a likely bovine origin. In addition, immunological testing of associated tissue on the specimen also revealed a likely bovine origin. The assemblage of data suggested the specimen originated from a young calf with an extraordinarily bulbous cranial vault. Review of the veterinary literature revealed one condition that could explain the strange morphology of the specimen, hydrocephaly (Ubelaker, et al., 1991). Congenital hydrocephalus in calves can produce an enlarged, human-appearing, dome-shaped cranial vault. The calves frequently do not survive and if the facial structures are absent, the resulting calvarium can easily be confused with human. Search for a comparative documented specimen eventually culminated in the collections of the Institut für Tierzucht und Haustiergenetik in Giessen, Germany, whose curator, Prof. G.W. Rieck, kindly provided a comparative documented specimen showing morphological features matching those of the forensic specimen. This case documents the extent of research required by some unusual specimens and the information gained from the endeavor. In archeological and paleontological contexts, such specimens could be confused with pathological humans and potentially could be misidentified as human fossils.

STATURE

Existing formulae for the estimation of living stature from skeletal remains generate estimates with a reasonable degree of accuracy. However, the reliability of stature information reported during life may be questionable. Although military records may contain actual measurements of living stature, most reports of the stature of missing persons derive either from verbal accounts of family members and friends or from the individual's driver's license. Research has shown that neither source should be regarded as highly accurate (Brues, 1958). Stature information on the driver's license usually is self-reported and may represent an individual "wish" rather than objective measurement. Giles and Hutchinson's (1991) analysis of anthropometric data from members of the United States Army suggests that men overestimate their stature by a larger amount than do women. Their review of data from 8,000 individuals re-

vealed that men exaggerated their stature by an average of 2.5 cm, while the figure for women was only about 1 cm. Willey and Falsetti (1991) report similar findings of measured vs. self-declared stature among a university student sample.

"RACE"

There are few words employed in physical anthropology that stir more varied reactions than "race." Because the word means different things to different people, it is especially vulnerable to misinterpretation. To many physical anthropologists and other scientists, the use of the word "race" harks back to previous centuries when overly simplistic and erroneous notions of human variation prevailed and racist attitudes worked their way into the scientific literature. Research in human biology has documented the complex nature of human variation and the nonexistence of "human types" as fixed morphological groups.

Yet any routine glance at the daily newspaper or television will confirm that a race concept is alive and well in contemporary America. As biological anthropologists, we realize that human variation cannot be accurately summarized utilizing the racial types of centuries past. At the same time, as anthropologists, we must recognize that a popular concept of race does exist, but that whereas this concept has some biological components, it largely is socially and historically derived. Thus when a police officer asks a forensic anthropologist "What race was he?," he/she is not revealing an 18th-century scientific world view, but rather an inquiry about the ancestry or social classification of the individual that might assist identification.

There are two approaches that forensic anthropologists can utilize in providing this type of vital information to law enforcement yet staying within the bounds of modern scientific nomenclature. One approach is to estimate the likely geographic ancestry of the individual through an assessment of the morphological traits available (Brace, 1995). The other approach is to estimate how individuals would have been socially classified in their communities based upon the observed morphology of the remains. The strength of the language utilized should relate to the physical evidence. In making these assessments, the forensic anthropologist must be cognizant of the temporal and geographic variability in popular "racial" classification.

The popular social classification system in North America is not entirely applicable elsewhere. The social meanings of the terms American Indian, white or black in South Dakota will differ from those in Latin America or in the Near East. Many Americans use the term Hispanic to refer to someone of Latin American ancestry, but in Central and South America the term would be overly simplistic and not adequately reflect the biological variation of the population.

American Indian census data provide an example of the anthropological dynamics of temporal change in group classification within America. In the 1980 United States census, only 339,475 Native Americans were listed as living on or around United States reservations (excluding Alaska). Approximately 891,208 Native Americans were enrolled in tribes recognized by the United States government. In contrast, about 1,478,523 individuals declared themselves American Indian in the 1980 census (Ubelaker, 1988). The marked increases in population numbers suggested for the American Indian population in recent decades by census figures undoubtedly include cultural shifts in how people regard themselves and how they are looked upon by their communities.

Snipp's (1986) analysis of the 1980 census figures reveals additional dimensions to the complexities of the American "race" issue. The 1980 Census of Housing and Population offered Americans 15 choices of group classification. The census also inquired about "ancestry." Snipp (1986) suggests that over 1,500,000 Americans considered themselves to be of the American Indian "race," but a whopping 6,754,800 indicated American Indian "ancestry." Any effort by forensic anthropologists to predict how such individuals would have been classified must be cognizant of the complexities of these issues.

FACIAL REPRODUCTION AND PHOTOGRAPHIC SUPERIMPOSITION

Research and experience in recent years has advanced considerably our ability to estimate what someone looked like from his skull (facial reproduction). This technique is utilized in forensic anthropology primarily as a last resort to communicate to the public through the media what a person represented by recovered remains might have looked like. The goal here is to produce a likeness sufficiently similar to the missing person so that someone who knew him will come forward with the information needed to make the positive identification. Recent advances in this procedure include a system developed with the FBI that enables such reproductions to be generated by computer (Ubelaker and O'Donnell, 1992). This procedure calls for close collaboration between the artist and anthropologist. The same equipment can be utilized to compare a photograph of a person with a recovered cranium and mandible to judge if both originated from the same individual (Ubelaker et al., 1992). In such problems, the technique is most useful in ruling out a suspected individual (Ubelaker, 1994).

Methods of facial reproduction have proven useful in skeletal biology primarily for education purposes. Discussions with contemporary American Indian groups on repatriation issues have revealed broad interest in this technique as a means of revealing to them what their ancestors may have looked like. The educational value of such reproductions in paleoanthropology has long been recognized, but their accuracy has been debated (Montagu, 1947; Roberts, 1993; Stringer and Gamble, 1993). The forensic experience with this technique in cases of known individuals helps to increase its accuracy and realism in such educational applications.

POSITIVE IDENTIFICATION

A central goal of forensic anthropology analysis is positive identification. Hopefully, enough accurate information about an individual represented by human remains can be generated to allow identification. Such a positive identification requires that information unique to the individual is demonstrated to be present both in the once-living individual and in the recovered remains. Usually such evidence consists of dental restorations that can be compared by forensic odontologists with radiographs or dental records. In their absence, forensic anthropologists can provide such identification through comparison of anatomical details visible in radiographs taken during life. Examples of such identifications include those made from features of cranial anatomy, especially morphology of the frontal sinus (Ubelaker, 1984), anatomical detail visible on the scapula and proximal humerus (Ubelaker, 1990b), and details of the vertebral spine (Fenger et al., 1996). In all such identifications, documented comparative collections of human remains are invaluable to demonstrate the range of variation (or lack thereof) in the features examined. As techniques for extracting molecular data from bones and teeth continue to improve, identifications by this approach will undoubtedly increase (Boles et al., 1995).

TIME SINCE DEATH

Estimates of postmortem interval within forensic anthropology usually are made from observations on the extent of decomposition of the body, bones and associated artifacts, associated plant growth (Willey and Heilman, 1987) or datable artifacts, entomological evidence (Rodriguez and Bass, 1983), or analysis of volatile fatty acids in the soil (Vass et al., 1992). Much of this knowledge has resulted from observations on documented cases, but increasingly from controlled research experimentation as well. The decay facility at the University of Tennessee has stimulated considerable research in this area. Much of the knowledge generated from this research has increased awareness of the variability of the postmortem decomposition process and the variety of variables involved.

The knowledge about postmortem change in human remains uniquely assembled in forensic anthropology is needed to properly interpret archeologically recovered human

remains. For example, in 1971, T.D. Stewart and the author excavated a large secondary ossuary from southern Maryland containing at least 188 individuals and dating from the late prehistoric or early historic period (Ubelaker, 1974). The sample was especially valuable demographically since ethnohistorical sources suggested the ossuary represented all of the deceased from a specific time period who were interred collectively at a periodically conducted burial ceremony. Since the surviving group members went to great lengths to assemble the remains of all who had died since the last burial ceremony, the resulting ossuary approached a complete sample and avoided many of the sampling pitfalls of skeletal samples from large cemetery contexts.

Demographic reconstruction from the ossuary samples enabled the projection of the crude mortality rate for the people represented. This information coupled with knowledge about the total number of individuals in the sample would allow a valuable estimate of the size of the population contributing to the ossuary if the time period represented by the bone deposit was known. This was a problem since the ethnohistorical sources were unclear on this matter and since the ossuary predated them. During excavation, data were collected on the extent of skeletal articulation. Since the ossuary represented all accumulated dead over a period of time, some who had died immediately prior to the burial ceremony were represented by completely articulated skeletons. Those who had died early in the period were largely decomposed and they were represented by disarticulated bones. An intermediate category was recognized consisting of individuals who were partially articulated. These represented individuals who had died sufficiently long before ossuary burial that decomposition was advanced, allowing the body to become segmented upon preparation for burial, yet still retaining bone articulation within those segments (Fig. 4). Assuming a relatively constant rate of deaths, the data on articulation offered information about the time interval of the ossuary. The proportions of individuals in the various states of articulation were directly related to the time interval represented by the ossuary (Ubelaker, 1974). The information needed to complete the equation and to calculate population size consisted of the rate of soft tissue decomposition. The only source of such information was through the retrospective work in forensic anthropology (Fig. 5). Analysis of forensic cases of known individuals with known death and recovery dates permits insight into the nature and rate of the decomposition process (Rodriguez and Bass, 1983). This information, coupled with that gleaned from experimental work, permits interpretation of archeological situations like the ossuary described here.

TAPHONOMY

Casework in forensic anthropology produces unique information about human taphonomy. Forensic cases originate in a tremendous variety of situations that, once documented, produce considerable information about postmortem change. Case analysis, as well as research in forensic anthropology, has significantly increased our knowledge about the skeletal effects of chewing by rodents, dogs, bears, sharks, and other animals. This knowledge helps us to better interpret alterations on archeologically recovered human remains. Plant growth, especially root growth, can be used in forensic contexts to estimate postmortem interval. Many cases reveal how plant root growth within bone can lead to bone fracture and other alterations that can mimic trauma or trampling effects. Figure 6 illustrates a human rib from a forensic case involving a skeletonized gunshot victim. Roots from associated vegetation had permeated the skeleton. In the illustrated rib, a small root entered through a natural foramen. Once inside, the growing root expanded in diameter until the rib fractured. Later, if the plant was no longer present and the root decomposed, the fracture could easily be misinterpreted as resulting from trauma or trampling.

Taphonomy represents one of the most important areas within forensic anthropology. No other professionals possess more knowledge of human skeletal postmortem change than forensic anthropologists and other skeletal biologists. Such knowledge frequently

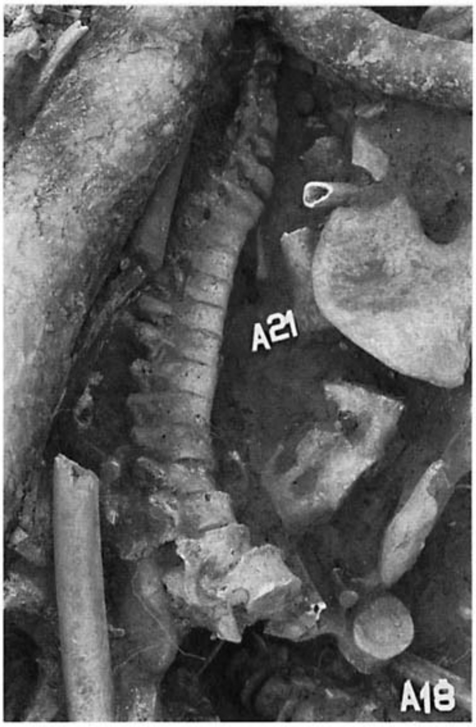

Fig. 4. Articulated vertebrae found within the archeological context of an ossuary from Maryland.

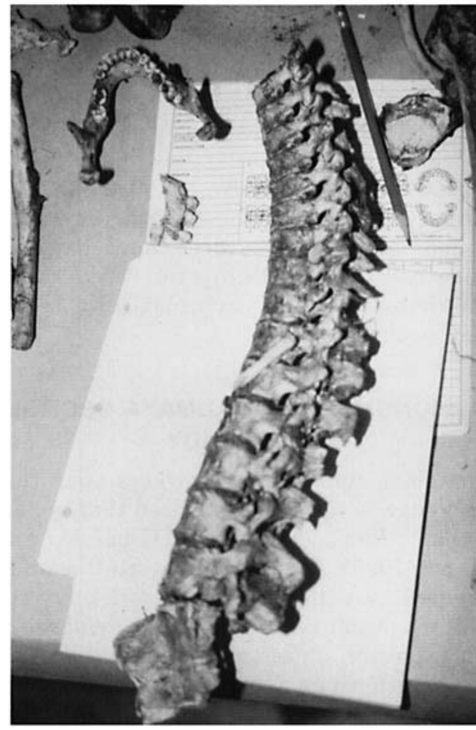

Fig. 5. Articulated vertebrae with desiccated soft tissue maintaining bone articulation from a modern forensic case.

Fig. 6. Human rib from a forensic case with fracture created by root penetration and growth.

is critically needed to differentiate evidence of foul play from normal anatomical variation and natural postmortem processes. Important evidence for sharp force trauma can easily be confused with naturally occurring skeletal surface features, the erosive canals of postmortem weathering, or the effects of animal chewing. Conversely, the knowledge gained about these features through the forensic casework facilitates interpretation of similar evidence on archeologically recovered human remains.

TAPHONOMY AND TRAUMA, A GEORGIA CASE STUDY

In 1993, construction workers operating heavy power equipment noticed that apparent bones had been recovered (Ubelaker and Adams, 1995). Analysis at the Smithsonian revealed that the remains were likely very old (lack of soft tissue, extensive evidence of sun exposure, algae growth, and bone surface weathering). Observation of the long bones also revealed a series of patterned fractures (Fig. 7) of a type referred to in the orthopedic pathology literature as "butterfly" fractures. These are irregular, but basically triangular-shaped fractures of the diaphysis, typically produced when a pedestrian is struck by an automobile or similar such trauma. Biomechanically, compression occurs on the impact side, producing a wide complex fracture, while tension is produced on the opposite side, resulting in a simpler fracture. When found on the bones of a decedent, in the absence of antemortem remodelling, the alterations may suggest perimortem (at or about the time of death) trauma.

Past experience with similar types of fractures initially suggested for the Georgia bones perimortem trauma of the type discussed above. Closer examination of the fractured surfaces, however, revealed that their coloration was distinct and markedly more "fresh" appearing than the other exposed outer surfaces of the long bones. This suggested that the fractures were recent in origin, not perimortem as initially suspected. Apparently, the heavy power equipment had accidently passed over the remains prior to their discovery, creating the fractures that had mimicked the better-known perimortem condition. Thus taphonomic knowledge was utilized to produce the correct diagnosis. The case in turn provided the new information that heavy power equipment can produce "trampling" effects that can mimic a previous known perimortem condition.

THE WEISS STUDY

In the author's experience, the study of taphonomy continually provides excellent examples of the intellectual "two-way street" between skeletal biology and forensic anthropology. The 1991 study of the remains of Carl Austin Weiss, the alleged assassin of Huey Long in Louisiana, represents a case in point (Ubelaker, 1996). Weiss was a 29-year-old physician accused of assassinating then–state senator Long in 1935. According to eyewitnesses, Weiss shot Long in the abdomen with a hand gun and was in turn shot many times by Long's bodyguards. This official version of events has been disputed subsequently with arguments that Weiss was not a violent person, had no substantial reason to kill Long, and was not displaying behavior suggestive that an assassination was planned. The problem was compounded in that internal autopsies were not performed at the time and a nurse who treated Long prior to his death reported that Long indicated to her that he had been struck on the lip (Zinman, 1993). Much of the material evidence was also allegedly lost shortly after the event. A popular countertheory was that Weiss had had words with Long, perhaps struck him with his fists, and was killed when the bodyguards overreacted and accidently killed Long as well.

In 1991, the remains of Weiss were exhumed. Trauma analysis revealed that he had been shot at least 20 times, and likely more. The projectile entrances were from all directions, but primarily from the back. Bones of the hands revealed no gross fractures that might suggest a fistfight, but they did reveal numerous small longitudinally oriented cracks in the diaphyses of several metacarpals. Microscopic analysis revealed these were not trauma-related stress fractures but rather postmortem fractures. Their presence in the bones of both hands and both feet supported the interpretation of

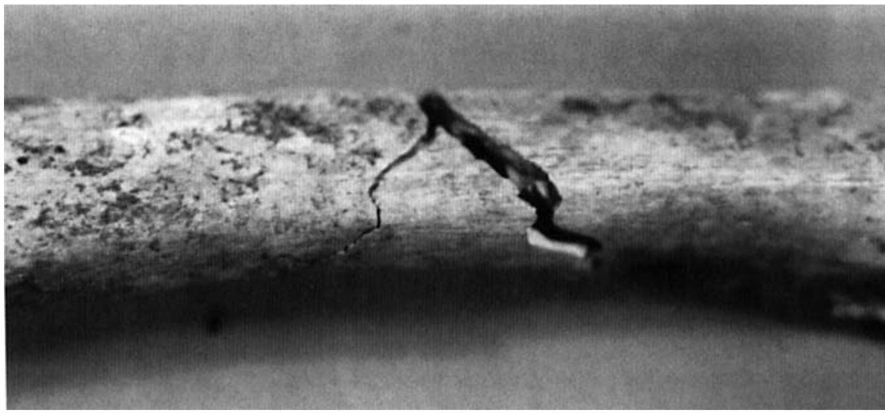

Fig. 7. Triangular-shaped fracture pattern in the diaphysis of a right humerus created by postmortem factors.

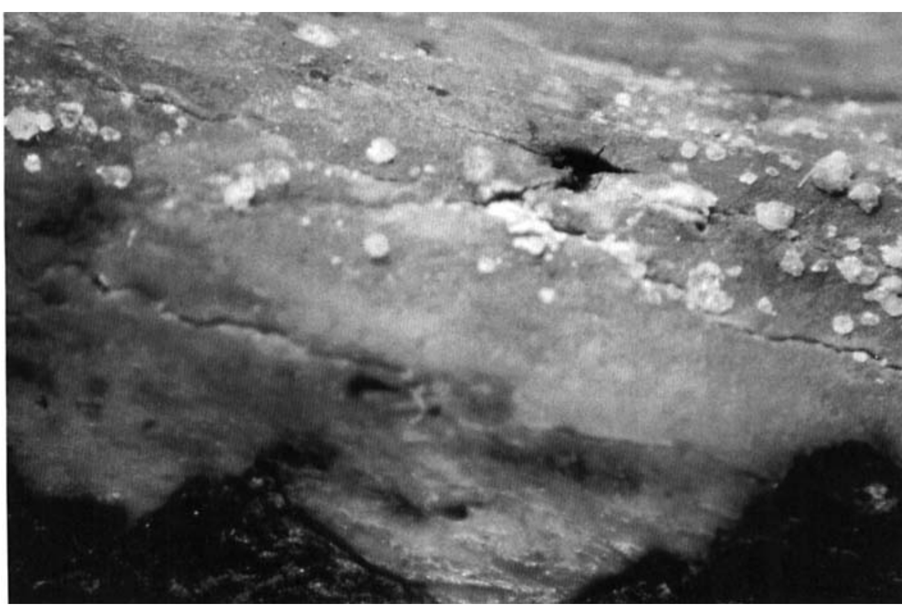

Fig. 8. White deposits of sulfuric composition on the diaphysis of the right second metacarpal of Weiss.

postmortem origin. Small white crystalline deposits (Fig. 8) on many of the bones proved to be of sulfuric origin and likely the result of body decomposition within the closed environment of the stainless steel coffin. When these deposits were removed, they left behind circular lesions that otherwise might appear to be either pathological or traumatic in origin.

Unusual black metallic-appearing deposits were present on the lingual surfaces of the teeth (Fig. 9) and most labial aspects of the anterior mandibular teeth. Analysis of these deposits revealed a composition of mercury. Analysis of other black deposits elsewhere on the skeleton proved these to be of sulfuric origin; thus the mercury was confined to the oral cavity. To test the hy-

Fig. 9. Dark metallic-appearing deposits of mercury on the lingual surfaces of the maxillary incisors of Weiss.

pothesis that Weiss might have ingested mercury that affected his behavior, the basal portions of hair and toenails that were recovered with the remains were analyzed. Sufficient mercury was not present in these materials, indicating that the mercury in his oral cavity was postmortem in origin. The likely source of the mercury was postmortem deterioration of his amalgam dental fillings, beginning at some point during his 55 years of interment in the underground vault (Ubelaker, 1996).

In short, analysis of the Weiss remains utilized knowledge acquired through forensic anthropology to assess the gunshot trauma and to differentiate relevant evidence for perimortem trauma from the numerous postmortem taphonomic changes. The analysis also generated new information on the postmortem effects of body decomposition (crystal and perforation formation) and on the long-term effects of burial on amalgam preservation (release of mercury and staining of the teeth). This knowledge augments our ability to interpret similar alterations in archeologically recovered specimens.

SKELETAL BIOLOGY OF CONTEMPORARY POPULATIONS

A central problem in forensic anthropology as well as in skeletal biology is that many of our techniques and the data available for analysis are derived from documented museum anatomical collections such as the Terry Collection (assembled at the beginning of the 20th century at Washington University School of Medicine in St. Louis) at the Smithsonian Institution (Galera et al., in press) and the Todd Collection at Case Western Reserve [assembled between 1912 and 1938 by their Department of Anatomy and now housed in the Cleveland Museum of Natural History (Lovejoy et al., 1985)]. Although these collections have served the science well, questions remain about the applicability of data derived from them to contemporary forensic cases or to the peoples of the past studied by human skeletal biologists.

One remedy to this problem has been the creation of a forensic data bank by the physical anthropology section of the American Academy of Forensic Sciences. As the re-

mains of known individuals are studied in forensic contexts, noninvasive data are collected and added to the computerized data bank. The number of known individuals in the data bank in July 1996 was about 1,434, a size rivaling that of the large anatomical skeletal collections. Although sampling considerations exist with these data just as with any skeletal collection, the data bank offers the potential to revise techniques based upon data from individuals more similar to those recovered in forensic contexts to which the techniques are routinely applied (Jantz and Moore-Jansen, 1988). The data bank already has been utilized to revise existing stature calculation procedures (Jantz et al., 1995) and to contribute to new methods of age determination. The system has generated the popular "Fordisc" program allowing customized discriminate function estimates of sex and ancestry (Jantz and Ousley, 1993).

The unique data acquired through forensic analysis offer an unusual opportunity to examine aspects of the skeletal biology of contemporary populations. As early as 1977, Angel recognized the potential of forensic work in providing such information (Ubelaker, 1990a). He saw his own work as not only public service but as a method of collecting research information, as exemplified with his publications in 1974 on fractures and in 1976 on "Colonial to Modern Skeletal Change in the U.S.A."

The data bank concept expands on Angel's approach by pooling the data of many forensic anthropologists to create a database that all can draw from. Although convincing busy anthropologists to contribute remains a problem, the growing database potentially allows research into such topics as geographical variation and secular change in the skeletal biology of contemporary North Americans (Jantz and Ousley, 1996; Ousley and Jantz, in press), or related applications within general skeletal biology.

SUMMARY

Forensic anthropology represents a rapidly growing, dynamic subfield of physical anthropology. Although its roots extend back to the foundation of American physical anthropology, forensic anthropology has grown to embrace other areas of forensic science. The field is interdisciplinary, not only within anthropology, but within other sciences as well. The population and anthropological perspective acquired through training and research in anthropology represents a unique contribution of forensic anthropology within forensic science. Work in this area not only allows physical anthropologists to contribute their scientific skills to the resolution of problems within contemporary society, but also to gather information about the skeletal biology of contemporary Americans, assess the accuracy of existing techniques and gather information on trauma, taphonomy and related areas that are needed to properly interpret archeologically recovered remains. Our knowledge and skills in physical anthropology are needed to resolve issues in forensic science. We can contribute and we should.

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